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Diamond Light Source Proceedings, Vol 1, e66, page 1 of 5
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Contributed paper

SWING detection vacuum tunnel

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The SWING beamline is dedicated to the study of the small-angle X-ray scattering. In order to have the possibility to detect scattered intensity very close to the incident beam, it is absolutely necessary to install the detector at a long distance from the sample. In addition, it is easy to change the detector's position to access a wider angular range. A long and large vacuum chamber, the 'tunnel', has been designed with specific mechanisms inside to control the detector's position with micrometre resolution. Special attention has been given so as to offer a very useful device to the users. The paper will present the general design of the tunnel equipped with ancillary devices such as very narrow and stiff beam stoppers, diode holders and beam attenuators.

1. The first

Small-angle X-ray scattering experiments require placing the 2D detector at a (very) long distance from the sample, typically 0.5–8 m. As the energy range is in the region of the soft X-ray, it is important to protect the path of the diffracted beams in a vacuum. The 2D detector could be installed either directly in the vacuum tube or in the space following a vacuum tube that is closed with a large, X-ray transparent window. At Synchrotron SOLEIL, the SWING beamline leader has chosen the first of these two options because this solution seemed to offer the best performances and is the most convenient for users and operators. The X-ray beam is quasi-parallel and hence, the detector needs 'only' to be moved back to reach smaller scattering angles, which is one of the major advantages of the whole system. Therefore, the farther the detector is from the sample, which is placed directly upstream from the head of the tunnel, the better the access to smaller scattering angles that allow larger structures, up to 1 μm, to be investigated.

2. General specifications

The tunnel is situated inside the experimental lead hutch, after the experimental sample area. Figure 1 shows a top overview of the SWING beamline with the vacuum tunnel in place.

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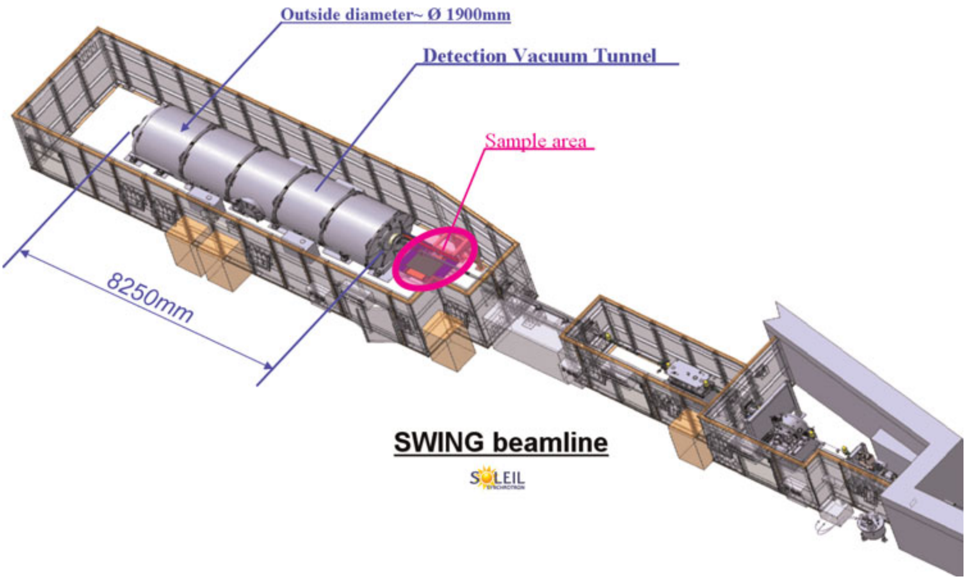

FIGURE 1. Top overview of the SWING beamline with the tunnel in place.

As the hutch is built in advance and as the tunnel is almost as long as the hutch itself, it necessary to take care of the installation process. The best way to put the large and long parts of the tunnel inside the hutch is to introduce them through the open roof with the help of the main crane of the synchrotron facility. The roof panels can always be disassembled to remove the tunnel parts, if necessary, for maintenance throughout the lifetime of the beamline.

The main advantage of such a long tube is its ability to reach very low angles. In this case, it is possible to capture some interesting information at an angle of 62.5 μrad when the detector table is situated far from the sample position. Alternatively, it is also possible to reach the 'wide' angle by setting the table as close as possible to the entrance. In this condition, the reachable widest angle is of the order of 15°.

The tunnel is designed to receive a large-sized flat panel detector with a frontal area of 1×1 m^2. The load capacity of the motorized table is 250 kg in order to be able to accept any heavy detector. Currently, the tunnel is equipped with a 'small' detector with a frontal area of 300×300 mm^2.

One of the most interesting characteristic and performance expected from this tunnel is the repeatability of each translation stage. Under beam operation, the users want to move from one position to another and need to be able to return to the previous position without the necessity of any correction. The wobble repeatability is of the order of 20 μm along the longest translation stage corresponding to the beam direction. To ensure this difficult specification, we took special care about the design of the whole assembly and the quality of the components.

In addition, for maintenance operations, the tunnel is designed to facilitate access inside the tube through two ways. The first access is through a large hole, situated on the side of the tunnel, which is closed with a vacuum door. This hole allows easy access to the detector and accessories. The hole is large enough so that a person can go inside the tunnel through it. The second is the possibility to manually open the back part of the tunnel, and sliding it on the open linear ball bearings. This large access (around 1.3 m) is necessary for heavy maintenance operations and to exchange the detector. It is possible to open the back of the tunnel in less than an hour.

Two evacuate the large volume of air of approximately 20 m^3 in less than an hour; two dry vacuum pumps are used. Their peak speed is around 600 $m^3\,h^{-1}$ with an ultimate pressure of 7×10^{-4} mbar.

3. Technical description

Table 1 shows the main technical specifications of the tunnel and the motorized translation stages.

In order to set the position of the 2D detector, it is placed on a motorized table that can be driven along all the three directions. The detector support looks like a mill table (see figure 2). The longest travel range is along the beam axis, with 6000 mm travel range. The horizontal and vertical displacements, with 400 mm travel range, give the possibility to move the detector in front of the incident beam to access to wider scattering angles. The linear guidance systems are of two types. The first one, exclusively used for the longest travel range of 6 m length, is carried out

Items	Technical specifications		
Available front surface	1×1 m^2		
Maximum load applied on the table	250 kg (2D detector, cables, water cooling pipes)		
Motorized table	**Travel range**	**Resolution**	**Reproducibility**
Along the beam axis	6 m	<50 µm	100 µm
Transversal direction	400 mm	~5 µm	50 µm
Vertical direction	400 mm	~5 µm	50 µm
Requested speeds			
Along the beam axis		~20 mm s^{-1}	
Transversal direction		~10 mm s^{-1}	
Vertical direction		~10 mm s^{-1}	
Vacuum			
Working vacuum level	2–4 × 10^{-2} mbar ⇒ limitation due to the current detector (it is possible to achieve a limit vacuum level of the order 5 × 10^{-4} mbar)		
Vacuum speed	5 × 10^{-2} mbar in 50 mn		
Ancillary equipments	**Resolution**		**Reproducibility**
3 *beamstoppers Dimensions of the smallest: 1 × 3 mm² – (beam size; 0.04 × 0.35 mm²*	<2 µm		20 µm
2 attenuators	<50 µm		–
1 diode	<100 µm		–
Video camera *To make a image of the beam downstream of the beamstoppers*			
Encoders	Absolute encoders everywhere		

TABLE 1. Main technical specifications

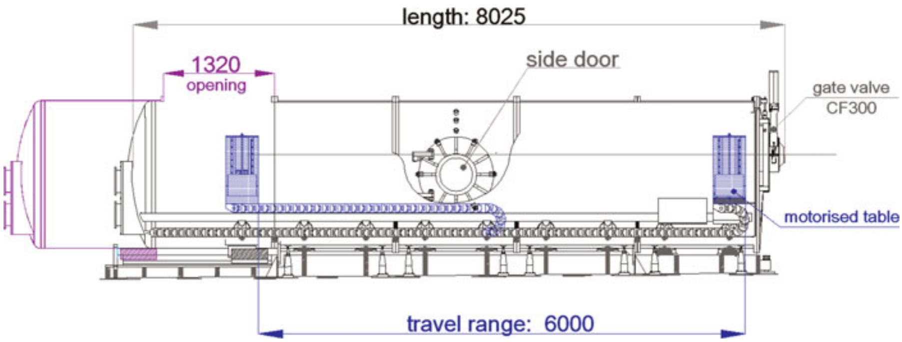

FIGURE 2. Internal side view of the tunnel with the main dimensions.

with open linear ball bearings built in tandem units with self-aligning design to accommodate misalignments. The second one uses profile rail guides for all the linear translation stages (motorized table and ancillary equipments).

Some ancillary devices are also installed inside the vacuum tunnel, which are directly linked to the mortorized table; they are the three beam stoppers, two attenuators, one diode and one video camera (see figure 3).

At the end, the tunnel is equipped with 18 motorized translation stages. All the displacements are ensured with preloaded, backlash-free ball screws and the position measurements are made with absolute encoders.

The 'nose' of the tunnel is also a specific equipment that increases the ease of use of the whole instrument. It is designed in a way such that it offers a set of conical intermediate vacuum pieces that adjust the length of the vacuum path in between the vacuum sample chamber and the tunnel and holds the vacuum window tight inside the tunnel. The external aperture diameter of the window is around 15 mm and the window is made of mica. The CF300 vacuum gate valve enables removing and modifying the set of conical intermediate vacuum pieces while leaving the tunnel under vacuum. In addition, the whole nose, including the gate valve, is movable along the vertical axis with the help of a motorized translation stage (±5 mm travel range). This translation permits, if necessary, to follow some little modifications of the orientation of the incident beam and to decentre the position

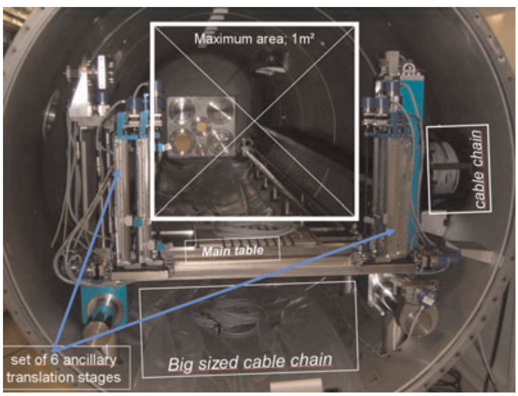

FIGURE 3. Front view of the open tunnel. Main motorized table and ancillary translation stages are visible

of the aperture from the centre to the edge of the window to access at a larger angular range in the wide-angle configuration.

4. Conclusion

The SWING detection vacuum tunnel is under operation since December 2007. It gives complete satisfaction to the users who are thus able to remotely change the angular range by changing the detector position without the necessity of any local intervention. They also greatly appreciate the high positioning repeatability of all translation stages and the useful ancillary equipments. It should be mentioned that this highly user-friendly and assumes to have a detector working under vacuum, which itself needs a specific concept.